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The NATO TG-25 Unattended Ground Sensors Field Experiment 2002

by Brian Mays, Hao Vu, and Nino Srour

ARL-TR-3010 September 2003

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The NATO TG-25 Unattended Ground Sensors Field Experiment 2002

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14. ABSTRACT In October 2002, the U.S. Army Research Laboratory (ARL) participated in the NATO TG-25 unattended ground sensors experiment held in Bourges, France. The field experiment was a joint international signature collection and vehicle tracking exercise with nine participating NATO countries. The experiment consisted of nine different ground vehicles that covered the heavy-tracked, light-tracked, heavy-wheeled, and light-wheeled class of ground vehicles. The vehicles were run in single vehicle and convoy formations. This report describes the raw signature data that was collected by the ARL during the TG25 field experiment. The raw signature data collected include acoustic array data at two geographic locations, three-axis seismic data at two geographic locations, and still infrared images of the vehicles at one location.					
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1. Background

1.1 Field Experiment Purpose and Goals

The North American Treaty Organization (NATO) research group SET-08/Task Group (TG)-25 on "Advanced Concepts of Acoustic and Seismic Technology" is involved in emphasizing acoustic and seismic concepts within Unattended Ground Sensors (UGS). The main objective of the group is to assess the potential technologies that can be cooperatively developed and assessed within NATO to provide low-cost battlefield sensors based on acoustic and seismic technology.

The approach adopted by TG-25 is as follows:

1. Evaluate emerging technologies for applicability to battlefield needs.
2. Develop cooperative efforts aimed at reducing costs to each participating country.
3. Evaluate potential of UGS to meet battlefield requirements.
4. Cooperate in known areas of overlap.
5. Cooperate on sensor environmental modelling.

The TG-25 has acquired participation from nine nations to include Canada, France, Germany, Italy, the Netherlands, Norway, Poland, the United Kingdom, and the United States. The group has worked on tasks with the primary objective of establishing quantitatively the military benefits that Acoustic and Seismic sensor systems offer. Although these technologies cover a wide range of applications, a few of these proposed topics will be selected for cooperation to include the following:

a. Propagation Modeling,

b. Signature Collection and Storage,

c. Standards,

d. Simulation and Modeling of Sensors,

e. Sensor Fusion,

f. Joint Field Experiments,

g. Unattended Ground Sensors, and

h. Sniper Detection.

In support of these tasks, a decision was made to further investigate the benefits of networking UGS systems and to demonstrate interoperability among participating nations. It was deemed necessary to organize a field-campaign in which each participant will collect data and provide real-time UGS system output to a network. Via the network, the UGS system output would be collected and visualized in real-time on a central server. Analysis of the collected data (i.e., data-fusion) would be carried out after the field-campaign.

In October 2002, under the auspices of the SET-08/TG-25 NATO research group, France hosted the Joint UGS field experiment campaign at the "Les Ormeaux" testing facility in Bourges. Appendix A shows the test site locations and the vehicle trajectories.

Apart from each team's own objectives concerning the field-campaign, the following collective goals have been defined:

- Centralized UGS system output. During the field-campaign, output data from each participant's UGS system(s) would be collected and displayed in real-time on a central server. This would demonstrate the potential of networked UGS systems, enabling the centralized and uniform collection of UGS systems' output.

- Exchange of sensor data. After the field-campaign, each TG-25 member would provide sensor data recorded during the field-campaign to other TG-25 members upon request.

- Analysis of networked UGS systems. After the field-campaign, the centrally collected UGS systems' output data would be made available to TG-25 members to determine the benefits of networking UGS systems.

- Field-campaign report. A report would be written to provide participants and others with information about the field-campaign.

- Demonstration for VIPs. During the field-campaign, a number of invitees were given the opportunity to attend the field-campaign. The purpose was to demonstrate current developments and to gain support for the funding of research in networked UGS systems.

1.2 Raw Data Collection Hardware

The data collection hardware that was used by the U.S. Army Research Laboratory (ARL) is referred to as the Data Fusion Testbed (DFT).[1] The DFT was developed by ARL to allow rapid in-field testing of various sensors and algorithms. The field-rugged, self-contained DFT can operate on battery or alternating current (AC) power, is remotely operated via wireless or RJ-45 network connection, and provides on-board recording of up to 56 channels of raw sensor data. The DFT can also host eight concurrent signal processing algorithms operating on the real-time

[1]Mays, B. *Electrical and Software Design Report for the Data Fusion Testbed*; ARL-MR-536; U.S. Army Research Laboratory. Adelphi, MD, July 2002.

sensor data. The algorithms can operate independently or fuze data locally prior to sending processed results to additional assets in the field. A final feature of the DFT allows remote clients to receive real-time sensor data. This allows high-level clients such as MATLAB or Labview clients to process field data and inject results into the network as if they were operating locally on the DFT. This feature avoids the costly step of porting software from a high level language for evaluation purposes. By using several DFTs, the backbone of a generic UGS field can be formed.

1.3 Acoustic Sensors

The acoustics sensors used were instrumentation-grade piezo-ceramic microphones. The specific microphones used were model number BL-1994 manufactured by Emkay Innovative Products. Emkay is a subsidiary company to Knowles, which is the common term used for the microphones. The sensitivity-vs.-frequency curve for the BL-1994 is shown in Appendix B.

1.4 Seismic Sensor

The seismic sensor used was a commercial tri-axial geophone. The specific unit is produced by Geo Space, LP, Inc. and contains three GS11D, 4.5-Hz, 4000-ohm coil resistance sensors packaged in a GSC-3C land case. The output sensitivity as a function of frequency is shown in Appendix C. Note curve C should be used due to the specific shunt resistor selected.

1.5 Infrared (IR) Sensor

IR images were collected for all of the vehicles used during the test. The images have various pass bye orientation to the camera and include both left and right turns in both approaching and receding directions. The IR sensor used for still image collection was the ALPHA uncooled IR camera, manufactured by Indego, Inc. The picture of the camera is shown in Figure 1. The specifications for the camera are shown in Appendix D.

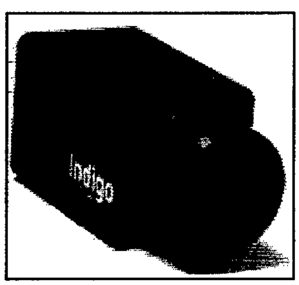

Figure 1. ALPHA uncooled IR camera.

The images were collected using a commercial frame grabber card, associated software, and laptop. The frame grabber card was manufactured by Video Capture Essentials. The captured images are stored as Microsoft Windows Bitmap files and had the following properties: height

640 (pixels), width 480 (pixels), 24-bit color stored as true color RGB. Even though the color format is true color, the actual data are gray scale.

2. Sensor Installations and Configurations

Two ARL DFT sensors were installed to support the field experiment. The first sensor is sensor number 6 and was located at Bourges site Z1 (see map in Appendix A). The second sensor was sensor number 8 and was located at Bourges site Z3. The locations and network address follow:

2.1 Z1: Sensor 6 (ARL Hardware Number)

Location N 47.00484°

E 2.68050°

Alt: 191 m

Position estimated with Garmin Receiver (accuracy 4 m)

IP Address: 192.168.10.40

Sensor ID number used in NATO Messages : 120

Geodetic survey location:

N 47° 0.29145 min

E 02° 40.8274 min

Alt: 238.2-m ellipsoid

Seismic sensor is 170 cm from the center of acoustic array. Acoustic array and seismic sensor are both aligned to True North.

2.2 Site Z1 Surroundings

Sensor location 6, site Z1, had only one reflective source and that was the electronics hut. The hut was approximately the same separation as the array from site Z3, but at an angle of ~265°.

Sensor 6 at Z1 site is not operational on the last day of the field test, October 24, 2002. Sensor 8 at Z3 site remained operational for the entire series of tests on that same day.

2.3 Z3: Sensor 8 (ARL Hardware Number)

Location N 47.00293°

E 02.68576°

Alt: 183 m

Position estimated with Garmin Receiver (accuracy 4 m)

IP Address: 192.168.10.60

Sensor ID number used in NATO Messages : 370

Geodetic survey location:

N 47° 0.1768 min

E 02° 41.14357 min

Alt: 232.7-m ellipsoid

Seismic sensor is 193 cm from the center of acoustic array. Acoustic array and seismic sensor are both aligned to True North.

- Locations in WGS-84 coordinates
- NATO Sensor ID numbers were unique for all participants

2.4 Site Z3 Surroundings

Site Z3 has an old farm building ~100 m from the array. The walls were intact and created an efficient reflective source. The wall facing the array was parallel to the road between Z1 and Z3. The distances and locations of the surroundings at Z3 are mapped out in Figure 2.

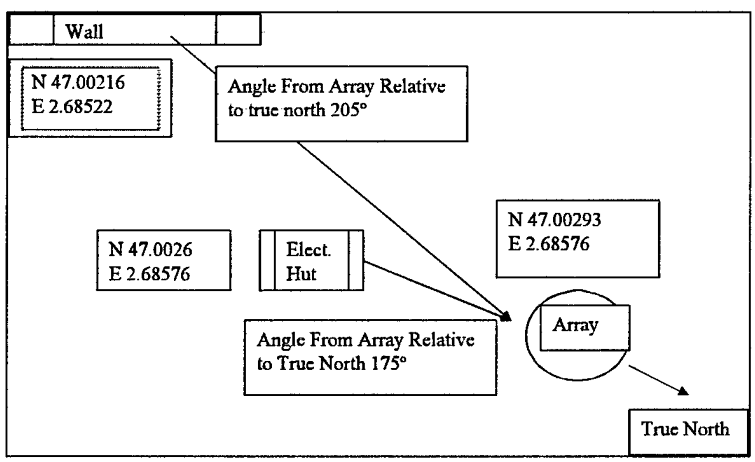

Figure 2. Locations of local Z3 surroundings.

Controlling Computer "Magenta" was configured with IP Address 192.168.10.90.

Both sensors were configured to connect to the "Spider" socket server at IP Address 192.168.10.31 and port 1000.

2.5 IR Camera: (Located at Z3)

Camera Location: N 47.00269°

E 02.68582°

Alt: 172 m

Distance from camera perpendicular to middle of the track: 5.2 m

Distance from camera to center of intersection: 27.8 m

Angle from camera to intersection: 135° from magnetic north.

Figure 3 shows the IR camera position relative to the road.

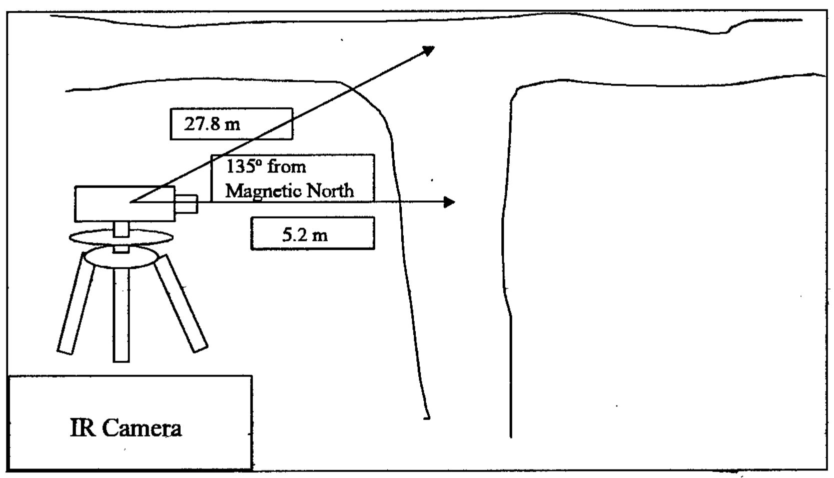

Figure 3. IR camera position at Z3.

2.6 Sensor Microphone Configurations and Seismic Configuration

The sensor configurations for Sensor 8 site Z3 are as follows:

Group 0: Array of Microphones. The microphones were configured as a 7-element 4-ft circular array with topology shown in Figure 4.

Group 0 used junction box serial number (SN): 213(3 temp label)

Channel 1: Mic SN 101

Channel 2: Mic SN 117

Channel 3: Mic SN 48

Channel 4: Mic SN 63

Channel 5: Mic SN 19

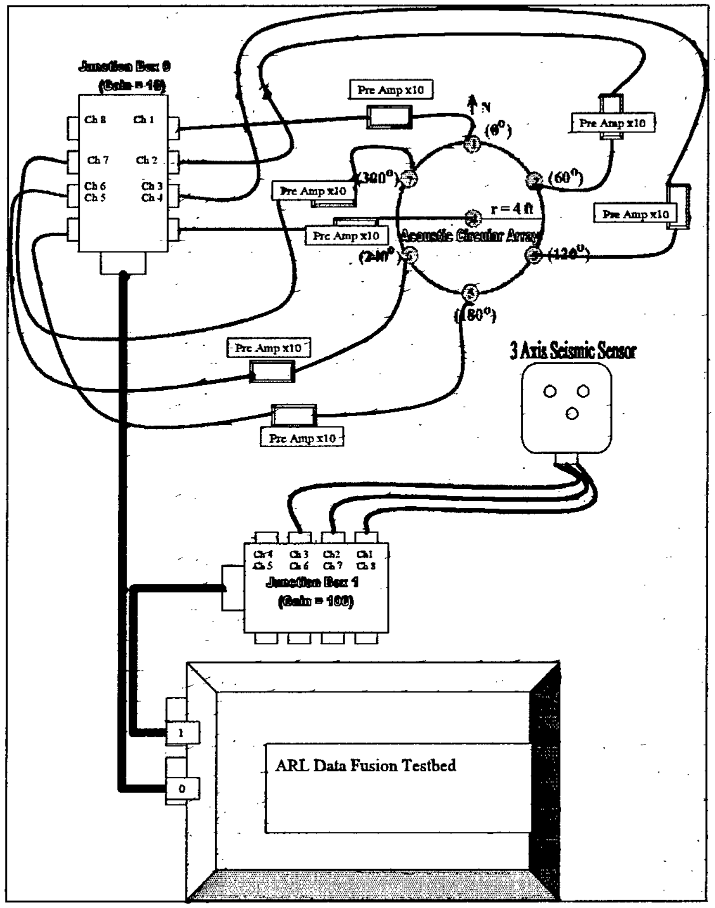

Figure 4. Array topology and signal connections.

Channel 6: Mic SN 122

Channel 7: Mic SN 26

Channel 8: No Connection

Group 1: 3 channels of seismic data from tri-axis seismometer with ARL SN 6.

Group 1 used junction box SN: 2–15

Channel 1: North

Channel 2: East

Channel 3: Vertical

Channels 4–8: No Connections

The sensor configurations for Sensor 6 site Z1 are as follows:

Group 0: Array of Microphones. The microphones were configured as a 7-element 4-ft circular array with topology shown in Figure 4.

Group 0 used junction box SN: (C-1 and B-5 temp label)

Channel 1: Mic SN 85

Channel 2: Mic SN 32

Channel 3: Mic SN 107

Channel 4: Mic SN (no label)

Channel 5: Mic SN 24

Channel 6: Mic SN 38

Channel 7: Mic SN 6

Channel 8: No Connection

Group 1: 3 channels of seismic data from a tri-axis seismometer

Group 1 used junction box SN: (Not Recorded)

Channel 1: North

Channel 2: East

Channel 3: Vertical

Channels 4–8: No Connections

2.7 Sensor Data Acquisition Parameters

The settings for Sensors 6 and 8 were identical and are as follows:

Group 0 Sample Rate: 2048 Hz

Group 1 Sample Rate: 1024 Hz

Group 0 Gain 100× (33 in hardware setting): 10× in junction box 10× in mic preamp

Group 1 Gain 100× (44 in hardware setting): 100× in junction box no preamp on seismic

Group 0 Cutoff 625 Hz (66 in hardware setting)

Group 1 Cutoff 312 Hz (77 in hardware setting)

2.8 Sensor 6 Failure During Test

General Notes: On the evening of October 21, 2002 and into the morning of October 22, 2002, a severe thunderstorm went through the test area. The CPU in Sensor 6 was damaged. The sensor was replaced with the development system that was on site as a backup. All of the sensors remained in order so the data sets will have the same calibration files. There should be no noticeable difference in the data, but the change in sensors is noted for completeness.

3. Vehicle Test Matrix

Table 1 is the test matrix that provides a detailed record of the actual vehicle (Appendix E) runs during the field test. It records the number of runs that had taken place during the field test, the date when the runs occurred, the time when the vehicle(s) started their runs, the time when the vehicle(s) ended their runs, what type of target(s), the speed of the target(s), and how many targets were involved during the runs. It also provides the footnote that documents additional information that occurred during the runs.

4. Description of Raw Data

The raw acoustic and seismic data that were collected at the TG-25 field experiment have the same fundamental format specification. The data are organized into one file per eight analog signal channels. For each site, the first group (group 0) of channels contained the acoustic array data on channels 1–7 and the second group (group 1) contained the three-axis seismic data. The seismic group had three channels 1–3, containing the North, East, and Vertical components, respectively. Channels 8 on group 0 and channels 4–8 on group 1 had no sensor elements connected and should be ignored. During the tests, each vehicle run produced two data files per site location. The filenames have the basic format of year_month_day_hour_min_sec_SensorNumber_ GroupNumber. The Sensor number indicates the site where the data were collected, and the group number indicates which set of eight analog channels are contained in the file.

The data within each file are stored in a binary file that is specified in Appendix F. The fundamental structure is a 40 byte header followed by a packet of raw data. The size of the raw data packet is calculated from the header information but is in this case 1 s of analog data for the eight channels specified by the group number. The blocks of headers followed by data repeat throughout the entire data file, which spans the entire vehicle run. The binary files are easily read into application by calculating the size parameters from the header fields, and an example MATLAB (Matrix Laboratory) program is included in Appendix G, which demonstrates the reading of the raw data files.

Table 1. Test matrix.

Run #	Date	RawData Filename	IR Image Filename	Start time	Stop time	Target type	Num vehs	Speed kph	Notes
Trial 1	10/16/02	2002_10_16_08_27_10_Sens8_Grp0 2002_10_16_08_27_10_Sens8_Grp1 2002_10_16_08_27_24_Sens6_Grp0 2002_10_16_08_27_24_Sens6_Grp1	Trial1_16Oct02_AMX30 Trial2_16Oct02_AMX30	0827	0840	AM × 30	1	20	Artillery fire 8:32
1	10/16/02	2002_10_16_13_12_34_Sens6_Grp0 2002_10_16_13_12_34_Sens6_Grp1 2002_10_16_13_12_44_Sens8_Grp0 2002_10_16_13_12_44_Sens8_Grp1	Run1a_16Oct02_AMX30 Run1b_16Oct02_AMX30 Run1c_16Oct02_AMX30 Run1d_16Oct02_AMX30	1312	1344	AM × 30	1	20	Z1 is magnetic north. Z3 is True North. Magnetic North is offset by 2° 35 min counterclockwise from True North
2	10/16/02	2002_10_16_13_56_02_Sens6_Grp0 2002_10_16_13_56_02_Sens6_Grp1 2002_10_16_13_56_13_Sens8_Grp0 2002_10_16_13_56_13_Sens8_Grp1	Run2a_16Oct02_AMX30_broadside Run2b_16Oct02_AMX30_broadside Run2c_16Oct02_2AMX30 Run2d_16Oct02_2AMX30 Run2e_16Oct02_2AMX30	1356	1427	AM × 30 (2)	2	20	Separation 75 m
3	10/16/02	2002_10_16_14_54_37_Sens8_Grp0 2002_10_16_14_54_37_Sens8_Grp1 2002_10_16_14_54_57_Sens6_Grp0 2002_10_16_14_54_57_Sens6_Grp1	Run3a_16Oct02_VAB Run3b_16Oct02_VAB Run3c_16Oct02_VAB	1454	1515	VAB	1	30	Note: Run 1 is not Figure 8, on return driver skipped Z1 to Z3 path
4	10/16/02	2002_10_16_15_33_46_Sens8_Grp0 2002_10_16_15_33_46_Sens8_Grp1 2002_10_16_15_33_56_Sens6_Grp0 2002_10_16_15_33_56_Sens6_Grp1	Run4a_16Oct02_TRM2000 Run4b_16Oct02_TRM2000 Run4c_16Oct02_TRM2000 Run4d_16Oct02_TRM2000	1533	1554	TRM2000	1	30	—
5	10/17/02	2002_10_17_12_31_10_Sens8_Grp0 2002_10_17_12_31_10_Sens8_Grp1 2002_10_17_12_31_20_Sens6_Grp0 2002_10_17_12_31_20_Sens6_Grp1	Run5a_17Oct02_4AMX30 Run5b_17Oct02_4AMX30 Run5c_17Oct02_4AMX30 Run5d_17Oct02_4AMX30	1231	1303	AM × 30 (4)	4	20	Separation 75 m. Z1 was rotated ~3° clockwise and is now pointing to True North. Z3 is True North. High winds
6	10/17/02	2002_10_17_14_06_45_Sens8_Grp0 2002_10_17_14_06_45_Sens8_Grp1 2002_10_17_14_06_49_Sens6_Grp0 2002_10_17_14_06_49_Sens6_Grp1	Run6a_17Oct02_TRM10000 Run6b_17Oct02_TRM10000 Run6c_17Oct02_TRM10000 Run6d_17Oct02_TRM10000	1406	1430	TRM10000	1	30	High winds
7.1	10/17/02	2002_10_17_14_49_21_Sens8_Grp0 2002_10_17_14_49_21_Sens8_Grp1 2002_10_17_14_49_22_Sens6_Grp0 2002_10_17_14_49_22_Sens6_Grp1	Run7_1a_17Oct02_TRM10K_TRM2K Run7_1b_17Oct02_TRM10K_TRM2K	1449	1501	TRM10000 (1) TRM2000 (1)	2	30	Very high winds; Separation 75 m
7.2	10/17/02	2002_10_17_14_49_21_Sens8_Grp0 2002_10_17_14_49_21_Sens8_Grp1 2002_10_17_14_49_22_Sens6_Grp0 2002_10_17_14_49_22_Sens6_Grp1	Run7_2a_17Oct02_TRM2K_TRM10K Run7_2b_17Oct02_TRM2K_TRM10K	1501	1513	TRM2000 (1) TRM10000 (1)	2	30	Very high winds; Separation 75 m
8	10/17/02	2002_10_17_15_42_53_Sens8_Grp0 2002_10_17_15_42_53_Sens8_Grp1 2002_10_17_15_42_53_Sens6_Grp0 2002_10_17_15_42_53_Sens6_Grp1	Run8a_17Oct02_AMX10RC Run8b_17Oct02_AMX10RC Run8c_17Oct02_AMX10RC Run8d_17Oct02_AMX10RC	1542	1606	AM × 10-RC	1	30	Very high winds

Table 1. Test matrix (cont'd).

9	10/17/02	2002_10_17_18_32_19_Sens8_Grp0 2002_10_17_18_32_19_Sens8_Grp1 2002_10_17_18_32_27_Sens6_Grp0 2002_10_17_18_32_27_Sens6_Grp1	Run9a_17Oct02_2xAMX10RC Run9b_17Oct02_2xAMX10RC Run9c_17Oct02_2xAMX10RC Run9d_17Oct02_2xAMX10RC	1832	1855	AM × 10-RC (2)	2	30	Separation 75 m
10	10/17/02	2002_10_17_19_23_10_Sens8_Grp0 2002_10_17_19_23_10_Sens8_Grp1 2002_10_17_19_23_12_Sens6_Grp0 2002_10_17_19_23_12_Sens6_Grp1	Run10a_17Oct02_AMX30 Run10b_17Oct02_AMX30	1923	1938	AM × 30	1	20	Runs 10–16 only have direction 2 (i.e., Z5 to Z1 to Z3 to Z2 back to PC—to Z1 to Z3 to Z4 to Z5) Overshot the field after Z1 and backup to go down to Z3
11	10/17/02	2002_10_17_19_44_46_Sens8_Grp0 2002_10_17_19_44_46_Sens8_Grp1 2002_10_17_19_44_44_Sens6_Grp0 2002_10_17_19_44_44_Sens6_Grp1	Run11a_17Oct02_2xAMX30 Run11b_17Oct02_2xAMX30	1944	1958	AM × 30 (2)	2	20	Separation 75 m
12	10/17/02	2002_10_17_20_29_02_Sens8_Grp0 2002_10_17_20_29_02_Sens8_Grp1 2002_10_17_20_28_42_Sens6_Grp0 2002_10_17_20_28_42_Sens6_Grp1	Run12a_17Oct02_VAB Run12b_17Oct02_VAB	2029	2040	VAB	1	30	—
13	10/17/02	2002_10_17_20_56_15_Sens8_Grp0 2002_10_17_20_56_15_Sens8_Grp1 2002_10_17_20_55_57_Sens6_Grp0 2002_10_17_20_55_57_Sens6_Grp1	Run13a_17Oct02_TRM2000 Run13b_17Oct02_TRM2000	2055	2107	TRM2000	1	30	—
14	10/17/02	2002_10_17_21_08_25_Sens8_Grp0 2002_10_17_21_08_25_Sens8_Grp1 2002_10_17_21_08_06_Sens6_Grp0 2002_10_17_21_08_06_Sens6_Grp1	Run14a_17Oct02_TRM10000 Run14b_17Oct02_TRM10000	2108	2120	TRM10000	1	30	—
15	10/17/02	2002_10_17_21_22_04_Sens8_Grp0 2002_10_17_21_22_04_Sens8_Grp1 2002_10_17_21_21_46_Sens6_Grp0 2002_10_17_21_21_46_Sens6_Grp1	Run15a_17Oct02_TRM10K_TRM2K Run15b_17Oct02_ TRM10K_TRM2K	2121	2134	TRM10000 (1) & TRM2000 (1)	2	30	Separation 75 m
16	10/17/02	2002_10_17_21_41_51_Sens8_Grp0 2002_10_17_21_41_51_Sens8_Grp1 2002_10_17_21_41_49_Sens6_Grp0 2002_10_17_21_41_49_Sens6_Grp1	Run16a_17Oct02_p4 Run16b_17Oct02_P4	2141	2152	P4	1	30	—
Trial 2	10/21/02	2002_10_21_08_20_33_Sen6_Grp0 2002_10_21_08_20_33_Sen6_Grp1 2002_10_21_08_20_43_Sen8_Grp0 2002_10_21_08_20_43_Sen8_Grp1	Trial4a_21Oct02_AMX10P Trial4b_21Oct02_AMX10P Trial4c_21Oct02_AMX10P	0820	0859?	AM × 10P	1	~10	Loud Bang (Artillery) 0822 Aircraft 0830 Aircraft 0837 Aircraft 0842 Aircraft 0847 Aircraft 0856
17	10/21/02	2002_10_21_09_09_20_Sen6_Grp0 2002_10_21_09_09_20_Sen6_Grp1 2002_10_21_09_09_25_Sen8_Grp0 2002_10_21_09_09_25_Sen8_Grp1	Run17a_21Oct02_AMX10P Run17b_21Oct02_AMX10P	0909	0929	AM × 10P	1	10	Direction 1: Loud Bang (Artillery) 0909 Aircraft 0911 Aircraft 0923 Sensor 6 may have bad gain settings

Table 1. Test matrix (cont'd).

18	10/21/02	2002_10_21_09_43_45_Sen6_Grp0 2002_10_21_09_43_45_Sen6_Grp1 2002_10_21_09_43_53_Sen8_Grp0 2002_10_21_09_43_53_Sen8_Grp1 2002_10_21_10_00_08_Sen6_Grp0 2002_10_21_10_00_08_Sen6_Grp1 2002_10_21_10_00_16_Sen8_Grp0 2002_10_21_10_00_16_Sen8_Grp1	Run18a_21Oct02_2xAMX10P Run18b_21Oct02_2xAMX10P Run18c_21Oct02_2xAMX10P Run18d_21Oct02_2xAMX10P	0943–1000	1000–1015	AM × 10P (2)	2	<20	Directions 1 & 2: Separation: 75 m Each dir has a file; Sensor 6 may have bad gain settings. Have different weights, one has more armor than the other
19	10/21/02	2002_10_21_12_37_15_Sen6_Grp0 2002_10_21_12_37_15_Sen6_Grp1 2002_10_21_12_37_28_Sen8_Grp0 2002_10_21_12_37_28_Sen8_Grp1	Run19a- 21Oct02- 4xAMX30 Run19b- 21Oct02- 4xAMX30 Run19c- 21Oct02- 4xAMX30 Run19d- 21Oct02- 4xAMX30	1237	—	AM × 30 (4)	4	20	Helicopter running during the whole run started at 1237 Vehicles started at 1239 Sensor 6 may have bad gain settings
20	10/21/02	2002_10_21_13_46_59_Sen8_Grp0 2002_10_21_13_46_59_Sen8_Grp1 2002_10_21_13_47_13_Sen6_Grp0 2002_10_21_13_47_13_Sen6_Grp1	Run20a- 21Oct02- P4 Run20a- 21Oct02- P4 Run20a- 21Oct02- P4 Run20a- 21Oct02- P4	1346	1409	P4	1	30	Helicopter flying during run. Helo engine off 1357 Helo engine on 1408
21	10/21/02	2002_10_21_14_47_31_Sen8_Grp0 2002_10_21_14_47_31_Sen8_Grp1 2002_10_21_14_47_36_Sen6_Grp0 2002_10_21_14_47_36_Sen6_Grp1	Run21a- 21Oct02- AMX10RC Run21b- 21Oct02- AMX10RC Run21c- 21Oct02- AMX10RC Run21d- 21Oct02- AMX10RC	1447	1513?	AM × 10RC	1	20	—
22	10/21/02	2002_10_21_15_20_14_Sen8_Grp0 2002_10_21_15_20_14_Sen8_Grp1 2002_10_21_15_20_27_Sen6_Grp0 2002_10_21_15_20_27_Sen6_Grp1	Run22a- 21Oct02- 2xAMX10RC Run22b- 21Oct02- 2xAMX10RC Run22c- 21Oct02- 2xAMX10RC Run22d- 21Oct02- 2xAMX10RC	1519	1547	AM × 10-RC (2)	2	20	Helo loitering in background separation 75 m
23	10/22/02	2002_10_22_05_38_08_Sen8_Grp0 2002_10_22_05_38_08_Sen8_Grp1	—	0538	0557	AM × 30	1	20	Sensor 6 down, Z3 only direction 2 (i.e., Z5 to Z1 to Z3 to Z2 back to PC—to Z1 to Z3 to Z4 to Z5)
24	10/22/02	2002_10_22_05_56_24_Sen8_Grp0 2002_10_22_05_56_24_Sen8_Grp1	—	0556	Did not record	AM × 30 (2)	2	20	Sensor 6 down, Z3 only direction 2 (i.e., Z5 to Z1 to Z3 to Z2 back to PC—to Z1 to Z3 to Z4 to Z5)
25	10/22/02	2002_10_22_06_49_34_Sen8_Grp0 2002_10_22_06_49_34_Sen8_Grp1	—	0649	Did not record	AM × 10	1	20	Sensor 6 down, Z3 only, ~0.5-hr run, rest is background noise measurements direction 2 (i.e., Z5 to Z1 to Z3 to Z2 back to PC—to Z1 to Z3 to Z4 to Z5)
26	10/22/02	2002_10_22_07_33_32_Sen8_Grp0 2002_10_22_07_33_32_Sen8_Grp1	—	0733	0748	AM × 10RC	1	20	Direction 2: (i.e., Z5 to Z1 to Z3 to Z2 back to PC—to Z1 to Z3 to Z4 to Z5)
27	10/22/02	2002_10_22_08_27_02_Sen6_Grp0 2002_10_22_08_27_02_Sen6_Grp1 2002_10_22_08_27_16_Sen8_Grp0 2002_10_22_08_27_16_Sen8_Grp1	—	0827	0901	Toyota Pickup	1	20	Sensor 6 Up; Replaced with development unit. Plane 0854

Table 1. Test matrix (cont'd).

28	10/22/02	2002_10_22_09_24_00_Sen6_Grp0 2002_10_22_09_24_00_Sen6_Grp1 2002_10_22_09_24_04_Sen8_Grp0 2002_10_22_09_24_04_Sen8_Grp1	—	0924	—	2× Toyota Pickup	2	20	Both Sensors Up
29	10/22/02	2002_10_22_12_28_21_Sen6_Grp0 2002_10_22_12_28_21_Sen6_Grp1 2002_10_22_12_28_21_Sen6_Grp0 2002_10_22_12_28_21_Sen6_Grp1	—	1214	1242	AM × 10RC, (1) AM × 10P (1)	2	20	Directions 1 & 2: Did not record dir 1 during this run. Due to conflict of IP addr. Record the 2 direction at 1228.
30	10/23/02	2002_10_23_12_49_04_Sen6_Grp0 2002_10_23_12_49_04_Sen6_Grp1 2002_10_23_12_49_17_Sen8_Grp0 2002_10_23_12_49_17_Sen8_Grp1	—	1249	—	AM × 30, (1) AM × 10P, (1) AM × 30, (1) AM × 10P (1)	4	20	Directions 1 & 2: Did calibration before this run. Sunshine, but high wind (8.1 m/s = 20–25 mph) Vehicles moving at 1253. The vehicles are interleave (amx30,amx10p,amx30,amx10p)
31	10/23/02	2002_10_23_14_02_28_Sen6_Grp0 2002_10_23_14_02_28_Sen6_Grp1 2002_10_23_14_02_34_Sen8_Grp0 2002_10_23_14_02_34_Sen8_Grp1	—	1402	1431	AM × 10P, (1) AM × 10RC, (1) AM × 10P, (1) AM × 10RC (1)	4	20	Directions 1 & 2:
32	10/23/02	2002_10_23_15_17_36_Sen6_Grp0 2002_10_23_15_17_36_Sen6_Grp1 2002_10_23_15_17_44_Sen8_Grp0 2002_10_23_15_17_44_Sen8_Grp1	—	1517	—	VAB, (1) AM × 10P (1)	2	20	—
33	10/24/02	2002_10_24_12_31_56_Sen8_Grp0 2002_10_24_12_31_56_Sen8_Grp1	—	1231	—	P4, (1) TRM2000 (1)	2	20	Direction 1: Sensor 8 only site Z3 rest of runs
34	10/24/02	2002_10_24_12_56_48_Sen8_Grp0 2002_10_24_12_56_48_Sen8_Grp1	—	1256	1310	P4, (1) TRM10000 (1)	2	20	Sensor 8 Only Z3
35	10/24/02	2002_10_24_13_36_59_Sen8_Grp0 2002_10_24_13_36_59_Sen8_Grp1	—	1336	1351	10rc, (1) vab, (1) trm2000, (1) trm10000 (1)	4	20	Plane will fly over until 1800. The vehicles are in order as labeled.
36	10/24/02	2002_10_24_14_19_48_Sen8_Grp0 2002_10_24_14_19_48_Sen8_Grp1	—	1419	1432	Pickup, (1) P4 (1)	2	20	Gain might be incorrect in group 0 of sensor 8 for runs 33–36
37	10/24/02	2002_10_24_14_57_37_Sen8_Grp0 2002_10_24_14_57_37_Sen8_Grp1	—	1457	1508	P4	1	20	—
38	10/24/02	2002_10_24_15_32_18_Sen8_Grp0 2002_10_24_15_32_18_Sen8_Grp1	—	1532	1546	10RC (2)	2	20	—
39	10/24/02	2002_10_24_15_50_28_Sen8_Grp0 2002_10_24_15_50_28_Sen8_Grp1	—	1550	1603	AM × 10RC, (1)	1	20	This 10RC is different than the one used in run 8.
40	10/24/02	2002_10_24_18_48_13_Sen8_Grp0 2002_10_24_18_48_13_Sen8_Grp1	—	1848	1902	AM × 10P, (1)	1	20	—

Table 1. Test matrix (cont'd).

41	10/24/02	2002_10_24_19_11_20_Sen8_Grp0 2002_10_24_19_11_20_Sen8_Grp1	—	1911	1934	AM × 10P (2)	2	20	—
42	10/24/02	2002_10_24_19_56_55_Sen8_Grp0 2002_10_24_19_56_55_Sen8_Grp1	—	1956	2008	AM × 10RC type 1	1	20	—
43	10/24/02	2002_10_24_20_32_30_Sen8_Grp0 2002_10_24_20_32_30_Sen8_Grp1	—	2032	2048	AM × 10RC type 2	1	20	—
44	10/24/02	2002_10_24_21_15_08_Sen8_Grp0 2002_10_24_21_15_08_Sen8_Grp1	—	2115	2127	AM × 10RC (1) AM × 10P (1)	2	20	—

A key field in the header file is the gain specified for the associated data packet. The gain table values are specified in Appendix H and require some additional interpretation for between the acoustic channels and the seismic channels. The gain table shows a box gain and a mic gain. For the acoustic channels, the total gain is the product of the two. For the seismic groups, only the box gain has significance because there is no preamplifier (Mic gain stage) to be concerned with. This implies that the total gain on the seismic groups is just the box gain and is not affected by any setting on the mic gain. For this test, the mic gain on the seismic groups was set to unity so the box gain equals the total gain shown in the chart.

---

5. Field Calibration Files

Calibration files were collected for both sensor arrays in the field on 23 October 2002. A 1-KHz calibration tone was injected into the microphones for ~10 s/channel. The calibrator used was a 94-dBSPL unit. A single calibration file was collected for each sensor; therefore, the tones must be searched for in the data files to extract the time window in which a specific microphone was being stimulated. The two files are 2002_10_23_12_06_Sen6_Grp0.dat and 2002_10_23_12_16_Sen8_Grp0.dat. The units were reconfigured to have the following data acquisition parameters for the calibration files:

Sample Rate = 4096 Hz

Gain = 10×

Cutoff Frequency = 1.25 KHz

Note that the meteorological conditions during the calibration collection were windy (gusts 20–25 mph and sustained winds of 15 mph).

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6. Contact Information for Data Requests

Requests for the raw sensor data described in this report and information on any restrictions in its distribution, should be sent to the following address:

U.S. Army Research Laboratory
Attn: AMSRL-SE-SA
2800 Powder Mill Rd
Adelphi, MD 20783

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Appendix A. Test Site Locations and Vehicle Trajectories

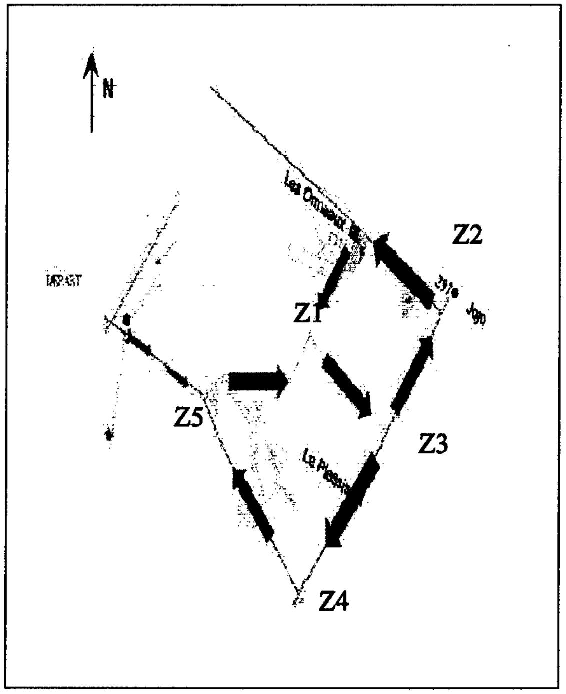

Figure A-1. Test site locations and vehicle trajectories.

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Appendix B. BL-1994 Sensitivity Specifications

MODEL NUMBER	SENSITIVITY AT 1KHZ dB RE 1V/1Pa	DC SUPPLY	AMPLIFIER CURRENT DRAIN (uA)	A-WEIGHTED NOISE (1KHZ EQUIVALENT SPL)	NOMINAL OUTPUT IMPEDANCE (OHMS)	COMMENTS
BL-1994	-69 +/- 3	3.0V	160	34.0dB MAX.	4000	BL-1785 WITH 38" CABLE ASSEMBLY

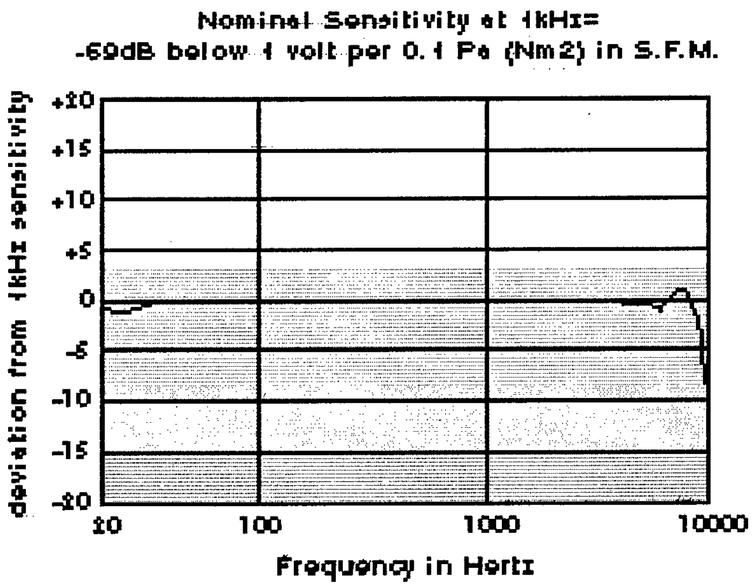

Figure B-1. BL-1994 sensitivity specifications.

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Appendix C. GS-11D Sensitivity Specifications

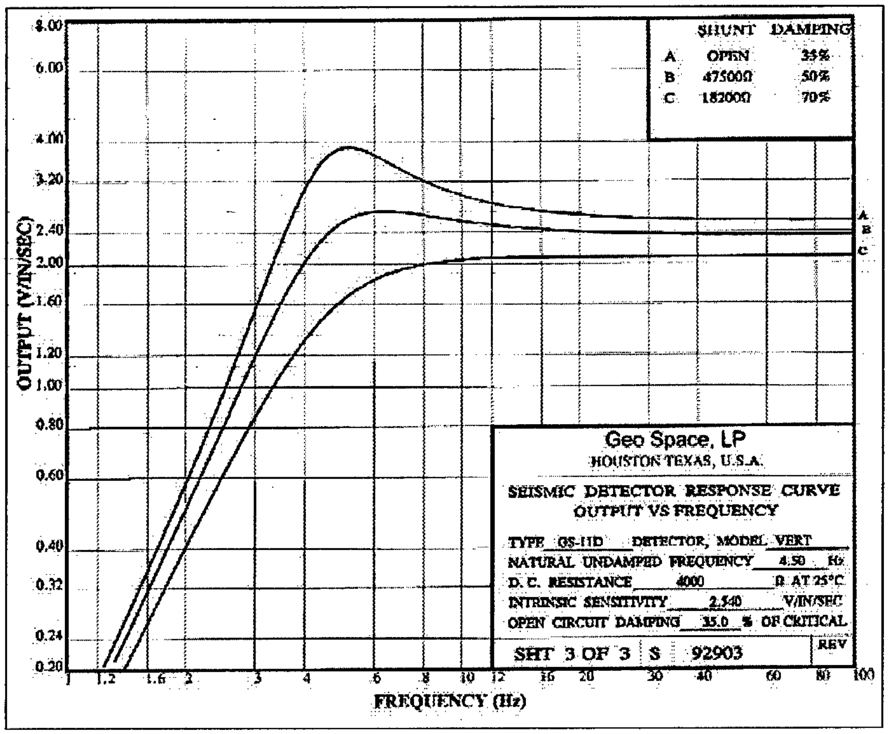

Figure C-1. GS-11D sensitivity specifications.

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Appendix D. ALPHA Infrared (IR) Camera Specifications

ALPHA Specifications	
Detector type	Uncooled Microbolometer
Detector spectral range	7.5–13.5 microns
Array format	160 H × 128 V pixels
Field of view (degrees)	25 H × 19 V

Figure D-1. ALPHA IR camera specifications.

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Appendix E. Vehicle Descriptions

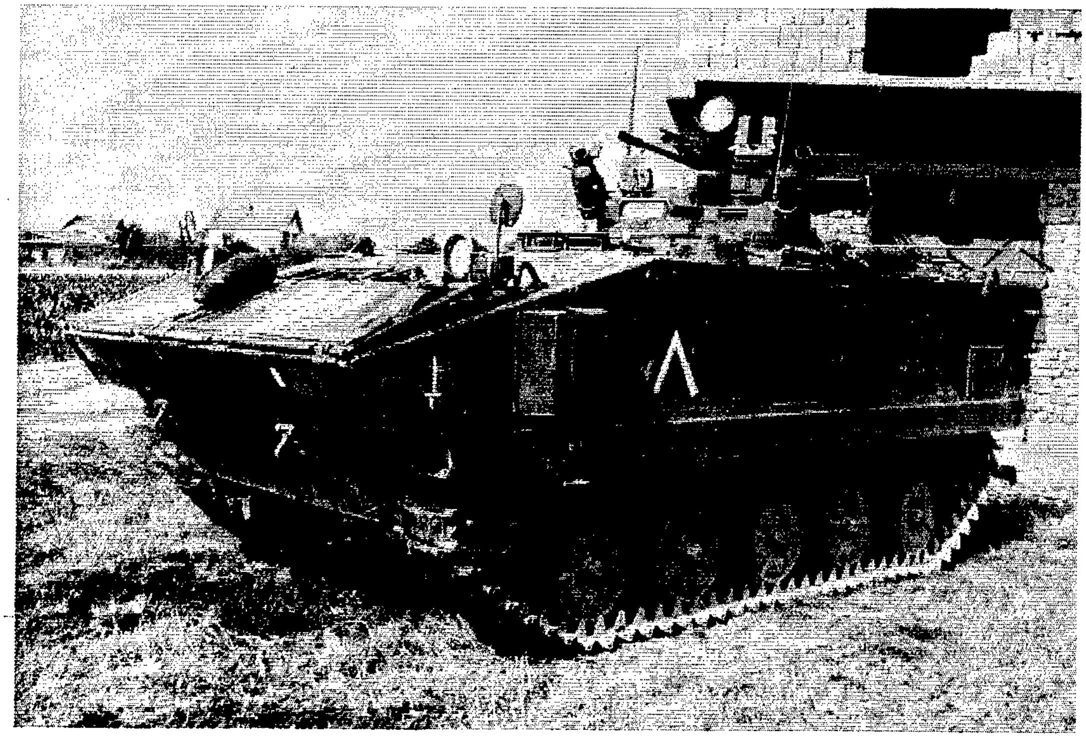

Figure E-1. AMX-10P: Infantry combat vehicle.

Combat weight: 14,500 Kg

Unloaded weight: 12,700 Kg

Track width: 425 mm

Length of track on ground: 2.93 m

Engine: Hispano-Suiza HS 115 V8 water-cooled supercharged diesel developing 260 hp at 3000 rpm

Transmission: preselective with four forward and one reverse gears

Suspension: torsion bar

Figure E-2. AMX-10RC: Reconnaissance vehicle.

Configuration: 6×6

Combat weight: 15,880 Kg

Unloaded weight: 14,900 Kg

Track: 2.425 m

Wheelbase: 1.55 + 1.55 m

Engine: Baudouin Model 6F 11 SRX diesel engine developing 280 hp at 3000 rpm

Transmission: preselective with four forward and four reverse gears

Suspension: hydropneumatic

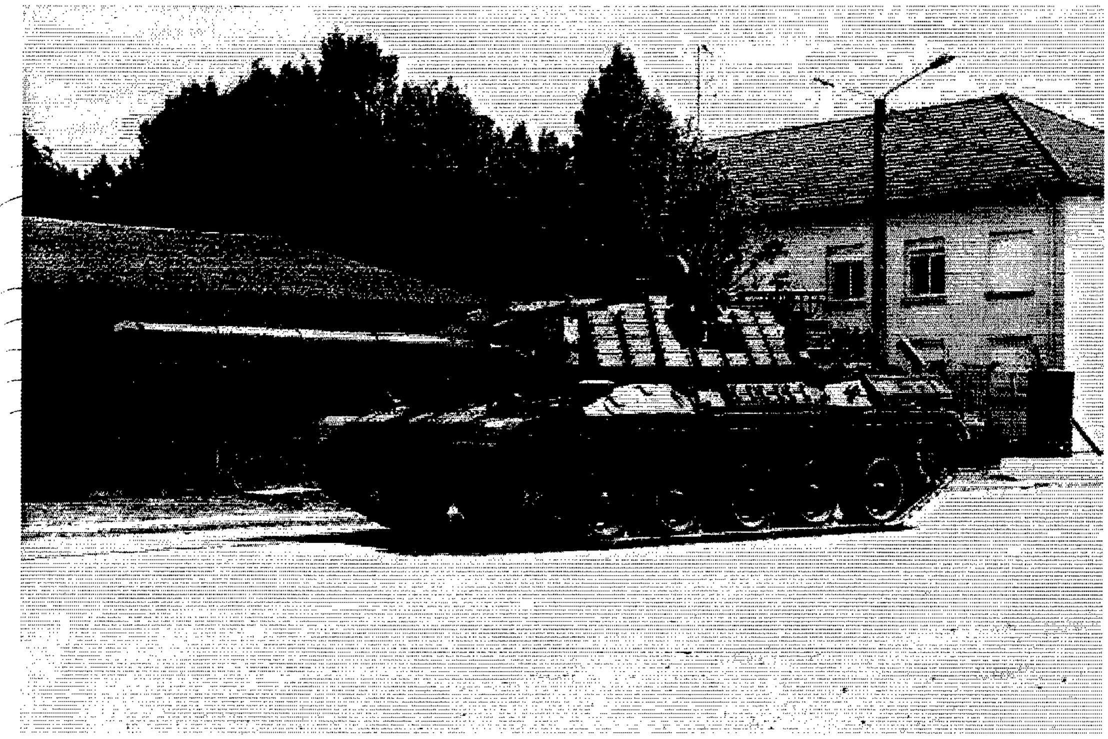

Figure E-3. AMX-30 MBT: Medium battle tank.

Combat weight: 36,000 Kg

Unloaded weight: 34,000 Kg

Track: 2.53 m

Track width: 570 mm

Length of track on ground: 4.12 m

Engine: Hispano-Suiza HS 110 12-cylinder, water-cooled supercharged multifuel developing 720 hp at 2000 rpm

Transmission: mechanical with five gears in both directions

Suspension: torsion bar

Figure E-4. CBH P4: Armored personnel carrier.

Configuration: 4×4

Combat weight:

Petrol engine: 3300 Kg

Diesel engine: 3380 Kg

Max load: 1100 Kg

Track: 1.4 m

Wheelbase: 2.4 m

Engine: 4-cylinder diesel developing 76 hp or 4-cylinder intercooled diesel developing 110 hp

Suspension:

(front) coil springs, antisway bar and double-acting telescopic hydraulic shock absorbers

(rear) coil springs and double-acting telescopic hydraulic shock absorbers

Figure E-5. TRM 10000: 10,000-Kg truck.

Configuration: 6 × 6

Loaded weight: 29,000 Kg

Unloaded weight: 13,520 Kg

Track: 2.015 m

Wheelbase: 4.3 m + 1.4 m

Engine: Renault MIDR 06-20-45 9.839 liters 6-cylinder supercharged exhaust diesel developing 326 hp at 2000 rpm

Gearbox: Model B.9.150, nine forward and one reverse gears

Suspension:

(front) semi-elliptical leaf springs (auxiliary and main springs), mechanical stops, and telescopic shock-absorbers

(rear) semi-elliptical leaf springs, mechanical stops

Figure E-6. TRM 200: Truck.

Configuration: 4×4

Loaded weight: 13,500 Kg

Unloaded weight: 5490 Kg

Track: 1.96 m

Wheelbase: 3.85 m

Engine: MIDR 06-02-26 W

Figure E-7. VAB: Armored personnel carrier.

Configuration: 6 × 6

Combat weight: 14,200 Kg with limited amphibious capabilities

Unloaded weight: 11,400 Kg

Track: 2.035 m

Wheelbase: 3 m

Engine: Renault MIDS 06-20-45 in-line water-cooled turbocharged 6-cylinder diesel developing 220 bhp at 2200 rpm. Original engine was a MAN D.2356 HM 72 in-line water-cooled 6-cylinder diesel developing 220 hp at 2200 rpm

Transmission: Transfluide with five forward and three reverse gears

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Appendix F. Data Format Specifications

F.1 Introduction

Every data packet will contain a header section and a data section. The header section comes with a fixed length of 40 bytes long. Depending on the sampling rate, the length of the data section is varied.

HEADER: Each field is a 16-bit unsigned integer in Little Endian Format (LSB) first.

Table F-1. Packet header format.

Fields	Name	Description	Value
1	Header ID	Distinguish different kind of data	2000 = acoustic data 0 = NULL data
2	Data type ID	Distinguish different type of data	0 = RAW data 1 = FFT data
3	Year	Years since 1900	99–
4	Month	—	1–12
5	Day	—	1–31
6	Hour	Hours after midnight	0–23
7	Minute	Minutes after hour	0–59
8	Second	Seconds after minute	0–59
9	Millisecond	Milliseconds after second	0–999
10	Sensor/group ID	Sensor ID/"signal condition" box ID	Sensor ID or w/ group ID
11	Sampling rate	Number of samples per second	2048 = Maximum sampling rate
12	Update rate	How often data are being transfer to host in hertz	—
13	Gain	Amplifier gain setting for "signal condition" box	Refer to Appendix C for gain table
14	Cutoff	Cutoff frequency setting for "signal condition" box	Refer to Appendix C for cutoff table
15	Full scale voltage	—	±5 volts
16	Number of channels per group	A/D channels	64 A/D channels that split into 8 channels per group
17	Days since sunday	Number of days from sunday	0–6
18	Board sampling rate	Used for calculating mux delays across groups	—
19	Active group mask	Bit 0–7 set indicates corresponding Group Active	—
20	Frame counter	Rolling counter used to detect lost frames	1–65535

Note: The size of each data packet can be calculated as follows:
RAW data packet (in bytes):
(((Header.Sampling Rate * Header.Number of Channels) / Header.Update Rate) * 2) + 40
NULL data = Contains only the header data
RAW data = Unprocessed data
FFT data = Fast Fourier data

F.2 Mux Delay Calculation

In applications using multigroup data, the mux delay between groups is calculated using Header Fields 18 and 19. The groups are scanned at the board sample rate making the base mux delay 1/board sample rate. The total delay is the base delay * the number of active groups between groups of interest, which is shown in field 19. Note that only active groups add to delay calculations. For example, an active group mask of 0 × 0B groups 0, 1, and 3 is active. The delay between 0 and 3 is a 2*base mux delay and the delay is 1*base mux delay between 0 and 1 and 1 and 3.

F.3 Data Block Specifications

Raw Data:

The raw data sent to the host is in individual blocks for each group. Within the block, the eight channels are stored as signed 16-bit integers (Little Endian) in an interleaved fashion. The interleave pattern is ([channel 1, 2, 3, 4, 5, 6, 7, 8][channel 1, 2....]). Note that within a sub-block (channels 1–8), the samples are simultaneous and each sub-block represents one sample event.

Appendix G. Sample MATLAB Program to Read Data Files

```
% Initialize look-up vector for gain factors as read from packet header
% Gain values range from 0 to 7 and map as follows:
%  0=10,1=100,2=100,3=1000,4=1000,5=10000,6=10000,7=100000
gain_vector=[1;10;10;100;100;1000;1000;10000];
file_name='2000_09_28_18_40_06_Sen2_Grp0.dat';
number_of_seconds = 7;
% All data are 16 bit unsigned int store in Little Indian Format
input_fd = fopen(file_name,'r','l');
 % Each data block preceded by a packet header
[Header,count] = fread(input_fd,20,'ushort');
sample_rate = Header(11);
update_rate = Header(12);
% loop through file extracting the data and stripping of packet headers
data=[];
for j=1:number_of_seconds
% Extract current gain values for packet.  The gains are stored in the low byte
% with the top nibble containing the gain value for the low channel group (1-4)
% and the low nibble used for the high channels.  The gain values stored are
% converted to real values via the gain lookup vector

  gain_channel_1to4 = gain_vector(bitshift(bitand(Header(13),hex2dec('000000f0')),-4)+1);
  gain_channel_5to8 = gain_vector(bitand(Header(13),hex2dec('0000000f'))+1);
% All of the data is read in as a two dimensional array with the row
% count set to the number of channels (8) and duration of 1 packet = sample rate/
% update rate
  clear temp
  [temp,count] = fread(input_fd,[8,sample_rate/update_rate],'short');
  temp(1:4,:) = temp(1:4,:)./gain_channel_1to4;
  temp(5:8,:) = temp(5:8,:)./gain_channel_5to8;
  data = [data,temp];
   % Grab next header
  [Header,count] = fread(input_fd,20,'ushort');
end
%convert to voltage full scall is +/- 5 volts
data = (data .*5.0)/2^15;
fclose(input_fd)
```

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Appendix H. Gain Table for Signal Conditioning Boxes

H.1 Gain Table for Signal Conditioning Boxes

Gain value selects the gain used in the signal conditioning boxes. It is a hex pair with the top nibble effecting the low four channels and the low nibble effecting the high four channels. The nibble values map to gains as in Table H-1.

Table H-1. Gain table.

Constant	Box Gain	Mic Gain
0	1	1
1	1	10
2	10	1
3	10	10
4	100	1
5	100	10
6	1000	1
7	1000	10
A	AGC ch0	AGC ch0
B	AGC ch4	AGC ch4

Notes: AGC = Automatic gain control
The A or B options enable AGC
on respective group of Channels with the
reference channel indicated above. Any other
valid gain sent to the group will disable AGC.

H.2 Cutoff Values for Signal Conditioning Boxes

Cutoff value selects the cutoff frequency used in the signal conditioning boxes. It is a hex pair with the top nibble effecting the low four channels and the low nibble effecting the high four channels. The nibble values map to frequencies as in Table H-2.

Table H-2. Cutoff frequency table.

0	No Change
1	20 kHz
2	10 kHz
3	5 kHz
4	2.5 kHz
5	1.25 kHz
6	625 Hz
7	312 Hz
8	156 Hz
9	78 Hz
A	39 Hz
B	19 Hz
C	10 Hz

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Arlington VA 22203-1714

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Ft Monmouth NJ 07703

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10 Whistler Lane
FT Monroe VA 23651-5850

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Washington DC 20375

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